SECTION 4

SAMPLE COLLECTION FOR ANALYSIS OF THE STRUCTURE AND FUNCTION OF FISH COMMUNITIES

4.1 General Considerations

4.1.1 A variety of methods, techniques, and equipment exist to sample fish populations and communities in lentic and lotic habitats. In addition, many procedures are available to analyze the fish data collected. Each technique has different assumptions, advantages and disadvantages. It is important to understand the attributes and characteristics of sampling equipment and techniques used in fish biosssessment so that valid conclusions can be drawn from the data. Sampling considerations and design (APHA, 1992; Lagler, 1956; Johnson and Nielson, 1983; Schreck and Moyle, 1990; Section 2, Quality Assurance and Quality Control) are important because aquatic biologists or fisheries scientists spend a major part of their time collecting data and the study results are determined by use of the data with a variety of techniques and equipment for an assortment of studies. Since fish populations are usually nonrandomly distributed and clumped in response to many habitat variables (Allen et al., 1992; Hendricks et al., 1980), the choice of sampling methods and equipment, the habitat and time of sampling, and frequency of sampling will depend on the data quality objectives of the study. For practical considerations, it is often easier to sample at certain places or time of the year (e.g., shallow water areas or during low flow). Therefore, all sampling gear is generally considered selective in sample collection to some degree (Everhart et al., 1975; Gulland, 1980; Henderson, 1980; Lagler, 1956, 1978; Ricker, 1971; Schnick and Moyle, 1990; Yeh, 1977; Zippin, 1956, 1958). Some procedures to reduce sampling bias through better sampling design are found in Armour et al. (1983), Cyr et al. (1992), Gulland (1980); Johnson and Nielsen (1983). The accurate and efficient collection of data can mean the difference between a successful management and research effort and a study that might end with inconclusive or inappropriate data.

4.1.2 In all bioassessment studies key physical, chemical, and biological indicators or parameters to be monitored should be selected carefully for the most direct cause and effect relationships. Some important indicators or parameters of biological integrity for consideration are found in Table 1. For a discussion of these variables and others, see Armour et al. (1983), Lagler (1956, 1978), Orth (1983), Plafkin et al. (1989), Rankin (1989), Ohio EPA (1987a, 1987b, 1989), and Section 8, Fish Bioassessment Protocols for Use In Streams and rivers, Subsection 8.13 Habitat Assessment and Physical/ Chemical Parameters, and references in Section 12, Fisheries Bibliography.

4.1.3 Table 2 is a general list of equipment and supplies needed for the collection of fish samples and biosurvey. The data quality objectives (DQOs), standard operating procedures (SOPs), sampling and analysis methods should determine the type of gear and supplies needed.

4.1.4 Figure 1, A-C are examples of fish field data sheets that can be adapted for field collections. Table 3 contains codes that can be used to

TABLE 1. GENERAL INDICATORS OF BIOLOGICAL/ECOLOGICAL INTEGRITY FOR FISH

Lakes and Reservoirs	Streams and Rivers
Structure and Function Components of Fish Populations and Communities	
Species composition	Species composition
Relative abundance	Relative abundance
Biomass	Biomass
Lengths	Lengths
Weights	Weights
Age and growth	Age and growth
Condition factor	Condition factor
Population numbers	Population numbers
Fecundity	Fecundity
Indices IBI	Indices IBI/Iwb
Health/Condition profile	Health/condition profile
Gross pathology, parasitism, disease incidence	Gross pathology, parasitism, disease incidence
State fish kills	State fish kills
Ice cover period	Pollution indices
Pollution indices	Ichthyoplankton index
Ichthyoplankton index	
Chemical Constituents	
Nutrients (N, P, total, soluble)	Nutrients (N, P, total, soluble)
DO, Alkalinity, conductivity, pH; nutrient dynamics	DO, alkalinity, conductivity, pH; nutrient dynamics
Habitat and Physical Variables	
Temperature	Temperature
Turbidity (secchi)	Suspended solids
Suspended solids	Hydrology
Water depth, area, retention time	Pool/riffle series
Substrate characterization	Substrate characterization
Shoreline development	Embeddedness
	Streambank stability
	Width of riparian zone, percent of stream cover

TABLE 2. GENERAL CHECKLIST OF FISH FIELD EQUIPMENT AND SUPPLIES

Boat(s)	____
Motor(s)	____
Paddles	____
Life preservers and flotation cushions	____
Fire extinguisher, (US Coast Guard approved)	____
First aide kit	____
Running Lights	____
Air Horn	____
Camera/film	____
Maps	____
Ice chests	____
Ice	____
Blue ice, soft pack	____
Dry ice	____
Portable light source	____
Waterproof notebook	____
Waterproof pencils, ink pens	____
Waterproof labels	____
Arm-length insulated water proof gloves	____
Hip boots	____
Rain gear	____
Feltsole neoprene chest waders	____
Paper towels	____
Aluminum foil	____
Thermometer	____
Water chemistry meters or water test kit	____
Secchi disk	____
Glass jars (4L, 2L, 1L) (chemical samples)	____
Hand tallys	____
Tape measure (100 yd. or meter)	____
Polaroid glasses	____
Dip nets	____
Seines	____
Gill nets	____
Trawls	____
Traps	____
Hoop nets	____
Electrofishing gear	____
Balance (weight scale)	____
Measuring board (50 cm)	____
Tubs	____
Buckets, livewells, coolers	____
Fish survey data forms	____
Habitat survey forms	____
Clip board with cover	____
Dissecting kit	____
Plastic bags, various sizes	____
10% Buffered formalin (formaldehyde solution)	____
Ethyl alcohol (ethanol) or isopropyl alcohol	____
Distilled or deionized water	____
Scale envelopes	____
Divider for measuring body proportions	____
Magnifier, pocket	____
Microscope, field	____
Dissecting microscope	____
Microscope slides and cover	____
Air pump, battery	____
Calculator	____
Marker, permanent black	____
Fish finder	____
Nylon-mesh fish cage	____
Sample containers	____
Data sheets	____
Patch kit for wader repair	____
Fiberglass hauling tanks	____
Anesthesia, MS222 (tricanemethane sulfonate)	____
Long forceps	____
Samll envelopes	____
Vials or small bottles	____
Scalpel or knife	____
Divider, fine-pointed, or dial caliper	____
Rule, stainless steel, metric	____
Other: ________________	
____________________	
____________________	
____________________	
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____________________	
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____________________	
____________________	
____________________	
____________________	

record external anomalies found on fish, and the codes are recorded on the fish field data sheet (Figure 1C).

4.1.5 Habitat Evaluation

4.1.5.1 A general site evaluation of each sampling location should be conducted during the sample processing because the range of habitats (riffles, runs, pools) can have a major effect on the data collected. Figure 2 contains a habitat description sheet for evaluating the surrounding topographical features and physical characteristics of fish sampling locations. The information can be used for calculating a Quality Habitat Evaluation Index (QHEI) described in Ohio EPA (1989) and Rankin (1989). Also, see Hughes et al. (1986; 1987), Hughes and Larsen (1988), Hunt (1992), Omernik (1987), Omernick and Gallant (1988), and Section 8, Fish Bioassessment Protocols For Use In Streams and Rivers.

4.1.6 Regional Reference Site Selection

4.1.6.1 Reference sites should be selected based on the following criteria:

4.1.6.2 Select site using standardized methods.

4.1.6.3 Select site least impacted sites that are typical of the region.

4.1.6.4 Avoid areas below point sources of pollution including known recovery areas (except large rivers).

4.1.6.5 Avoid areas of obvious habitat modification and nonpoint sources of pollution or impacts.

4.1.6.6 Select representative sites distributed by stream size.

4.1.6.7 Site can be maintained by continuing to resample the reference site on a once every ten years basis or less.

4.1.7 Fish Sampling Gear

4.1.7.1 Fish can be collected actively or passively. Active sampling methods include the use of seines, trawls, electrofishing, chemicals, and hook and line. Passive methods involve entanglement (gill nets, trammel nets, tow nets) and entrapment (hoop nets, traps, etc.) devices.

4.1.7.2 The chief limitations in obtaining qualitative and quantitative data on a fish population are gear selectivity and the mobility and rapid recruitment of the fish. Gear selectivity refers to the greater success of a particular type of gear in collecting certain species, or size of fish, or both. All sampling gear is selective to some extent. Two factors that affect gear selectivity are: (1) the habitat or portion of habitat (niches) to be sampled and (2) the actual efficiency of the gear. Another problem is that the efficiency of gear for a particular species in one area does not necessarily apply to the same species in another area. The skill and training

A. FISH FIELD DATA SHEET

Collection No. _______

State or Country: ______________________ County ___________

Locality: ____

____

Collectors: ____

Date: ____________________ Time: ____________________

Water : __________________ Temp.: __________ Air: ________

Shore vegetation: ______________________________________

Aquatic vegetation: ____________________________________

Stream width: ______________ Zmean: ____________________

Amax: ______________________ Zmean: ____________________

Shore: _____________________ Pool current: ______________

Bottom: ____________________ Riffle: ____________________

Weather: ____

Method of capture: ______________ Original preservative: __________

Water Chemistry: Secchi: ____________________

Depth	T°	pH	DO	Conductivity	Salinity

COMMENTS: ____

Figure 1. Example of a general fish field data sheet.

A. FISH FIELD DATA SHEET (CONTINUED)

Page ______ Of ______ Collection No. ______

State or Country: ______________________________ County ____________

Locality: ____

Collectors: ____

Date: __________________________ Time: __________________________

B. FISH FIELD DATA SHEET

Coll. No. ________

State or Country: ______________________________ County ____________________

Locality: ____

____

Water: ____

Vegetation: ____

____

Bottom: _____________________________________ Temp.: _________ Air: _______

Shore: ____

Distance from shore or stream width: ______________________ Current: _________

Depth of capture: ______________________________ Depth of water: ____________

Method of capture: ____

Collected by: ____ Date: _____________

Orig. preserv.: ____ Time: _____________

Weather: ____

____

Figure 1. Example of a general fish field data sheet.

C. FISH FIELD DATA SHEET

Field Crew: Collector/Recorder ____ **Time of Day:** ____ **Page** ____ **of** ____
River/Stream: ____ **Location:** ____
Date: ____
River Code: ____ **Sampler Type:** ____ **Time Fished:** '____" ____ **Total Seconds** ____
RM: ____ **Depth:** ____ **Observed Flow:** ____
Distance: ____ **Data Source:** ____ **Number of Species:** ____

Anomalies: A-anchor worm; B-black spot; C-leeches; D-deformities; E-eroded fins, F-fungus; L-lesions; M-multiple DELT anomalies, N-blind, P-parasites; Y-popeye; S-emaciated; W-swirled scales; T-tumors; Z-other/. [H-Heavy; L-Light are combined with anomalies A, B, and C]

SPECIES	# WEIGHED	TOTAL COUNTED	WEIGHT (GRAMS)					ANOMALIES					

Mass Weighing Convention: Total Weight (g) — 536 (12) — Number Weighed

Figure 1. Example of a general fish field data sheet. Adapted from OHIO EPA (1989).

SITE DESCRIPTION SHEET

Fish **QHEI SCORE:** [ ]

Stream______ RM______ Date______ River Code______

Location______ Crew:______

1] SUBSTRATE (Check *ONLY* Two Substrate *TYPE BOXES; Check all types present*); *SUBSTRATE SCORE:* [ ]

TYPE	POOL RIFFLE		POOL RIFFLE	SUBSTRATE QUALITY	
☐☐-BLDER /SLABS[10]	____ ____	☐☐-GRAVEL [7]	____ ____	Substrate Origin (Check all)	Silt Cover (Check One)
☐☐-BOULDER [9]	____ ____	☐☐-SAND [6]	____ ____	☐-LIMESTONE [1] ☐-RIP/RAP [0]	☐-SILT HEAVY [-2] ☐-SILT MODERATE [-1]
☐☐-COBBLE [8]	____ ____	☐☐-BEDROCK[5]	____ ____	☐-TILLS [1] ☐-HARDPAN [0]	☐-SILT NORMAL [0] ☐-SILT FREE [1]
☐☐-HARDPAN [4]	____ ____	☐☐-DETRITUS[3]	____ ____	☐-SANDSTONE [0]	Extent Of Embeddness (Check One)
☐☐-MUCK [2]	____ ____	☐☐-ARTIFIC.[0]	____ ____	☐-SHALE [-1]	☐—EXTENSIVE [-2] ☐—MODERATE[-1]
				☐-COAL FINES [-2]	☐—LOW[0] ☐—NONE[1]

TOTAL NUMBER OF SUBSTRATE TYPES: ☐> 4 [2] ☐— <= 4 [0]

NOTE: (Ignore sludge that originates from point-sources; score is based on natural substrates)

COMMENTS______

COVER SCORE: [ ]

2] INSTREAM COVER

TYPE (Check *All* That Apply)

☐-UNDERCUT BANKS [1] ☐-DEEP POOLS [2] ☐-OXBOWS [1]

☐-OVERHANGING VEGETATION [1] ☐-ROOTWADS [1] ☐-AQUATIC MACROPHYTES [1]

☐-SHALLOWS (IN SLOW WATER) [1] ☐-BOULDERS [1] ☐-LOGS OR WOODY DEBRIS [1]

AMOUNT(Check *ONLY* One or check 2 and *AVERAGE*)

☐ - EXTENSIVE > 75% [11]

☐ - MODERATE 25-75% [7]

☐ - SPARSE 5-25% [3]

☐ - NEARLY ABSENT < 5%[1]

COMMENTS:______

3] CHANNEL MORPHOLOGY: (Check *ONLY* One PER Category OR check 2 and *AVERAGE*) *CHANNEL:* [ ]

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATIONS/OTHER	
☐ - HIGH [4]	☐ - EXCELLENT [7]	☐ - NONE [6]	☐ - HIGH [3]	☐ - SNAGGING	☐ - IMPOUND.
☐ - MODERATE [3]	☐ - GOOD [5]	☐ - RECOVERED [4]	☐ - MODERATE [2]	☐ - RELOCATION	☐ - ISLANDS
☐ - LOW [2]	☐ - FAIR [3]	☐ - RECOVERING [3]	☐ - LOW [1]	☐ - CANOPY REMOVAL	☐ - LEVEED
☐ - NONE [1]	☐ - POOR [1]	☐ - RECENT OR NO RECOVERY [1]		☐ - DREDGING	☐ - BANK SHAPING
				☐ - ONE SIDE CHANNEL MODIFICATIONS	

COMMENTS:______

4] RIPARIAN ZONE AND BANK EROSION - (check ONE box per bank or check 2 and AVERAGE per bank) *RIPARIAN:* [ ]

"River Right Looking Downstream"

RIPARIAN WIDTH	EROSION/RUNOFF - FLOOD PLAIN QUALITY		BANK EROSION
L R (Per Bank)	L R (Most Predominant Per Bank)	L R (Per Bank)	
☐☐-WIDE>50m [4]	☐☐-FOREST, SWAMP [3]	☐☐-URBAN OR INDUSTRIAL[0]	☐ ☐-NONE OR LITTLE [3]
☐☐-MODERATE 10-50 [3]	☐☐-OPEN PASTURE/ ROWCROP[0]	☐☐-SHRUB OR OLD FIELD[2]	☐ ☐-MODERATE [2]
☐☐-NARROW 5-10m [2]	☐☐- RESID.,PARK,NEW FIELD [1]	☐☐-CONSERV. TILLAGE [1]	☐ ☐-HEAVY OR SEVERE[1]
☐☐-VERY NARROW 1-5m [1]	☐☐-FENCED PASTURE [1]	☐☐-MINING/CONSTRUCTION [0]	
☐☐-NONE[0]			

COMMENTS:______

POOL/GLIDE AND RIFFLE/RUN QUALITY *POOL:* [ ]

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY (Check *All* That Apply)	
☐- >1m [6]			
☐- 0.7-1m [4]	☐-POOL WIDTH > RIFFLE WIDTH [2]	☐-TORRENTIAL[-1]	☐-EDDIES[1]
☐- 0.4-0.7m [2]	☐-POOL WIDTH = RIFFLE WIDTH [1]	☐-FAST[1]	☐-INTERSTITIAL[-1]
☐- < 0.4m [1]	☐-POOL WIDTH < RIFFLE W. [0]	☐-MODERATE [1]	☐-INTERMITTENT[-2]
☐—<0.2m [Pool = 0]		☐-SLOW [1]	

☐- NO POOL[0]

COMMENTS:______

RIFFLE: [ ]

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
☐ - GENERALLY >10 cm,MAX>50 [4]	☐-STABLE (e.g.,Cobble, Boulder) [2]	☐-EXTENSIVE [-1] ☐-MODERATE[0]
☐ - GENERALLY >10 cm,MAX<50 [3]	☐-MOD. STABLE (e.g.,Pea Gravel) [1]	☐-LOW. [1] ☐-NONE[2]
☐ - GENERALLY 5-10 cm [1]	☐-UNSTABLE (Gravel,Sand) [0]	
☐ - GENERALLY < 5 cm [Riffle = 0]		

☐-NO RIFFLE[0]

COMMENTS______ *GRADIENT:* [ ]

6] Gradient (feet/mile):______ %POOL:______ %RIFFLE:______ %RUN:______

Figure 2. Site description sheet for evaluating the topogeographical features and physical characteristics of fish sampling location. Adapted from Ohio EPA (1989).

SITE DESCRIPTION SHEET (CONTINUED)

Is Reach Representative of Stream? (Y/N)_____ If Not: ____

Additional Comments/Pollution Impacts: ____

	GEAR	DISTANC	WATER CLARITY	WATER STAGE
FIRST PASS				
SECOND PASS				
THIRD PASS				

SUBJECTIVE RATING (1-10) ☐ AESTHETIC RATING (1-10) ☐

CANOPY (%OPEN) _______ GRADIENT: Ô-LOW Ô-MODERATE Ô-HIGH PHOTOS: _________

STREAM MEASUREMENTS: AVERAGE WIDTH:________ AVERAGE DEPTH:________ MAX. DEPTH ________

LENGTH	WIDTH	DEPTHS ⊳										POOL:GLD:RIF:RUN

CROSS-SECTIONS OF STREAM

DRAWING OF STREAM

Figure 2. Site description sheet for evaluating the topogeographical features and physical characteristics of fish sampling location. This part is used to record additional information about the sampling site and adjacent area. Adapted from Ohio EPA (1989).

TABLE 3. CODES UTILIZED TO RECORD EXTERNAL ANOMALIES ON FISH[1]

Anomaly Code	Description
D	Deformities of the head, skeleton, fins, and other body parts.
E	Eroded fins.
L	Lesions, ulcers
T	Tumors
M	Multiple DELT anomalies (e.g. lesions and tumors, etc.) on the same individual fish.
AL	Anchor worm - light infestation: fish with five or fewer attached worms and/or previous attachment sites.
AH	Anchor worm - heavy infestation fish with six or more attached worms and/or previous attachment sites.
BL	Black spot - Light infestation: spots do not cover most of the body with the average distance between spots greater than the diameter of the eye.
BH	Black spot - Heavy infestation: spots cover most of the body and fins with the average distance between spots less than or equal to the diameter of the eye.
CL	Leeches - Light infestation: fish with five or fewer attached leeches and/or previous attachment sites
CH	Leeches - Heavy infestation: fish with six or more attached leeches and/or previous attachment sites.
F	Fungus.
I	Ich
N	Blind - one or both eyes; includes missing and grown over eyes (does not include eyes missing due to popeye disease).
S	Emaciated (poor condition, thin, lacking form).
P	External parasites (other than those already specified).
Y	Popeye disease.
W	Swirled scales.
Z	Other, not included above.

[1]Adapted from Ohio EPA (1989).

of the personnel doing the sampling are also very important in sample collection.

4.1.7.3 Temporal and spatial changes in relative abundance of a species can be assessed under a given set of conditions if that species is readily taken with a particular kind of gear.

4.1.7.4 Passive collection devices usually require little specialized training to operate and can be used to collect data on relative abundance of many species. Passive methods, however, are very selective for some species. Gear type and design used are important in particular habitats to capture specific species or sizes of fish (Carter, 1954; Hubert, 1983; Starrett and Barnickol, 1955). Active methods are generally less selective and more efficient. Although the choice of method depends on the objectives of the fishery investigation and habitat to be sampled, active methods are generally preferred. However, the method selected must provide the information required from the survey or study. The biologist must decide whether he needs information on standing crop, catch per unit effort, qualitative information on the fishery, etc., and choose the sampling technique or techniques accordingly.

4.1.7.5 Sport fish, large specimens, and rare or endangered species should be identified in the field, measured (standard length, total length, body depth), examined for external anomalies, and if possible, released unharmed. If the fish are to be released unharmed, the method and equipment used must be selected appropriately. Some methods (e.g., gill nets) usually kill the fish.

4.2 Active Sampling Techniques

4.2.1 Seines

4.2.1.1 A haul seine is essentially a strip of strong netting hung between a stout cork or float line at the top and a strong, heavily-weighted lead line at the bottom (Figure 3). The wings of the net are often of larger mesh than the middle portion, and the wings may taper so that they are shallower on the ends. The center portion of the net may be formed into a bag to aid in confining the fish. At the ends of the wings, the cork and lead lines are often fastened to a short stout pole or brail. The hauling lines may be attached to the top and bottom of the brail by a short bridle. The quantiative factors of this gear are determined by the total length of the net, the mesh sizes used in its construction (especially in the bag), and whether or not the floatline remains on the surface during operation or under water with the leadline on the bottom. The size of these seines is usually determined by how they are retrived and the species sought.

4.2.1.2 Deepwater or haul seining usually requires a boat. One end of one of the hauling lines is anchored on shore and the boat plays out the line until it reaches the end. The boat then lays out the net parallel to the beach. When all of the net is in the water, the boat brings the end of the second hauling line ashore. The net is then beached as rapidly as possible without allowing the lead line to come off the bottom.

4.2.1.3 Straight seines (without bags) can usually be handled by two people. The method of playing out the seine and bringing it in may be similar to the haul seine or it may be pulled parallel to the shore for some distance before it is beached. The straight seine is generally used in shallow water where one member of the party can wade offshore.

4.2.1.4 Bag and straight seines vary considerably in dimensions and mesh size. The length may vary from 3 to 70 meters, and mesh size and net width vary with the size of the fish, depth of the water, and the habitat to be sampled.

4.2.1.5 Nylon seines are recommended because of the ease of maintenance. Cotton seines should be treated with a fungicide and dried after using to prevent deterioration. Nylon seines should not be left in the sun for prolonged periods of time or they will also deteriorate.

4.2.1.6 Seining is not effective in deep water unless the seine is deep enough to cover the area from surface to bottom. Seining is not effective in areas that have snags, large rocks and boulders, and sunken debris that may tear or foul the net. However, in selected areas seines can be very efficient in sampling fish. Although the results are expressed as number of fish captured per unit area seined, quantitative seining is very difficult. It must be applied consistently along several beaches of a waterbody to achieve a quantitative assessment. The method may be more useful in determining the variety of fish rather than the number of fish inhabiting the water.

4.2.1.7 Choice of seines will depend on the study design, and sampling methods and sizes of seines vary with habitat type.

4.2.1.8 Seining should be performed by at least two investigators, but having more helpers improves sampling effectiveness.

4.2.1.9 In riffles of wadable streams, e.g., the preferred method is the "foot shuffle" using a 3 m minnow seine with 1/4 inch mesh (6 mm) size. This kickset method consists of setting the net in the water perpendicular to the current. Investigators then enter the riffle approximately 3 m upstream from the net and actively disturb the substrate and overturn rocks or other debris. The net is then picked up and carefully examined for the presence of fish. In slower currents, it may be possible to pull the seine downstream, hooking into the bank after a distance of 5 to 10 m.

4.2.1.10 In pools, because larger seines are preferred, depth of water usually precludes effective kicksets. In such situations, pools are actively seined by pulling a 5 m seine with 1/4 inch mesh (6 mm) size through the pool either perpendicular or obliquely to the bank, or, in the case of very quiet water, upstream or downstream and parallel to the bank prior to hooking into shore and examining for fish.

4.2.1.11 Continue seining until two riffles and two pools or, in the absence of discrete habitats, a segment of at least 200 m has been sampled. Distance sampled should not exceed 500 m. Record total time spent collecting.

4.2.1.12 Record all information on field data sheets. Specimens kept for later identification or for voucher specimens should be preserved in 10% formalin solution (see Section 5, Fish Specimen Processing) and kept in separate jars by habitat type with inner and outer waterproof labels. Labels should contain locality data, habitat type, date, collectors names, and study collection numbers from the field sheets for that site.

4.2.2 Trawls

4.2.2.1 Trawls are specialized submarine seines used in large, open water areas of reservoirs, lakes, large rivers, estuaries, and oceans. They may be of considerable size and are towed by boats at speeds sufficient to overtake and enclose the fish. Four basic types are available: (1) the beam trawl used to capture bottom fish, (2) the otter trawl used to capture near-bottom and bottom fish, (3) the mid-water trawl used to collect schooling fish at various depths, and (4) surface tow nets used to collect fish at or near the surface. These trawls can be very effective on selected bottom, mid-water and surface oriented species at specific life history stages.

4.2.2.2 The beam trawls (Figure 4) have a rigid opening and are difficult to operate from a small boat. Otter trawls (Figure 5) have vanes or "otter boards", which are attached to the forward end of each wing and are used to keep the mouth of the net open while it is being towed. The otter boards are approximately rectangular and usually made of wood, with steel strapping. The lower edge is shod with a steel runner to protect the wood when the otter board slides along the bottom. The leading edge of the otter trawl is rounded near the bottom to aid in riding over obstructions. The towing bridle or warp is attached to the board by four heavy chains or short heavy metal rods. The two forward rods are shorter so that, when towed, the board sheers to the outside and down. Thus, the two otters boards sheer in opposite directions and keep the mouth of the trawl open and on the bottom. Floats or corks along the head rope keep the net from sagging, and weights on the lead-line keep the net on the bottom. The entrapped fish are funneled back into the bag of the trawl (codend). The size of the mesh in the codend (bag end of a net) will determine the species and life history stages caught.

4.2.2.3 The midwater trawl resembles an otter trawl with modified boards and vanes for controlling the trawling depth. Such trawls are cumbersome for freshwater and inshore areas, but can be used very effectively in marine and estuarine waters. Surface townets have been used very effectively for emigrant juvenile salmonids in northwest and Alaska estuaries for monitoring year class abundance.

4.2.2.4 A popular, small trawl consists of a 16 to 20 foot (5 to 6 meters) headrope, semiballoon modified shrimp (otter) trawl with 3/4 inch (1.9 cm) bar mesh in the wings and cod end. A 1/4 (0.6 cm) bar mesh liner may be installed in the cod end if smaller fish are desired. This small trawl uses otter boards, the dimensions of which, in inches, are approximately 24 to 30 (61 to 76 cm) x 12 to 18 (30 to 46 cm) x 3/4 to 1/4 inches (0.9 to 3.2 cm), and the trawl can be operated out of a medium-sized boat.

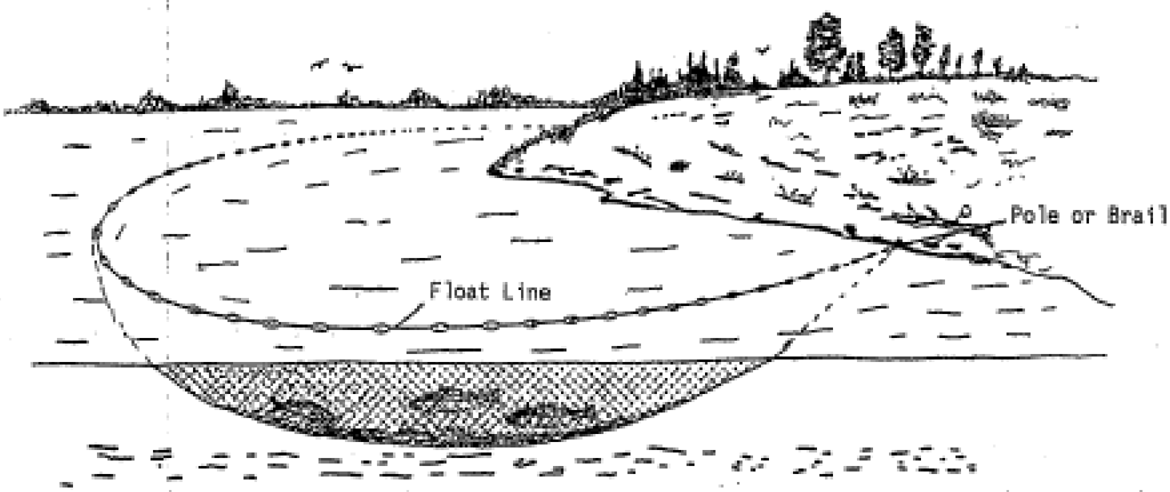

Figure 3. The Common Haul Seine. Modified from Dumont and Sundstrom (1961).

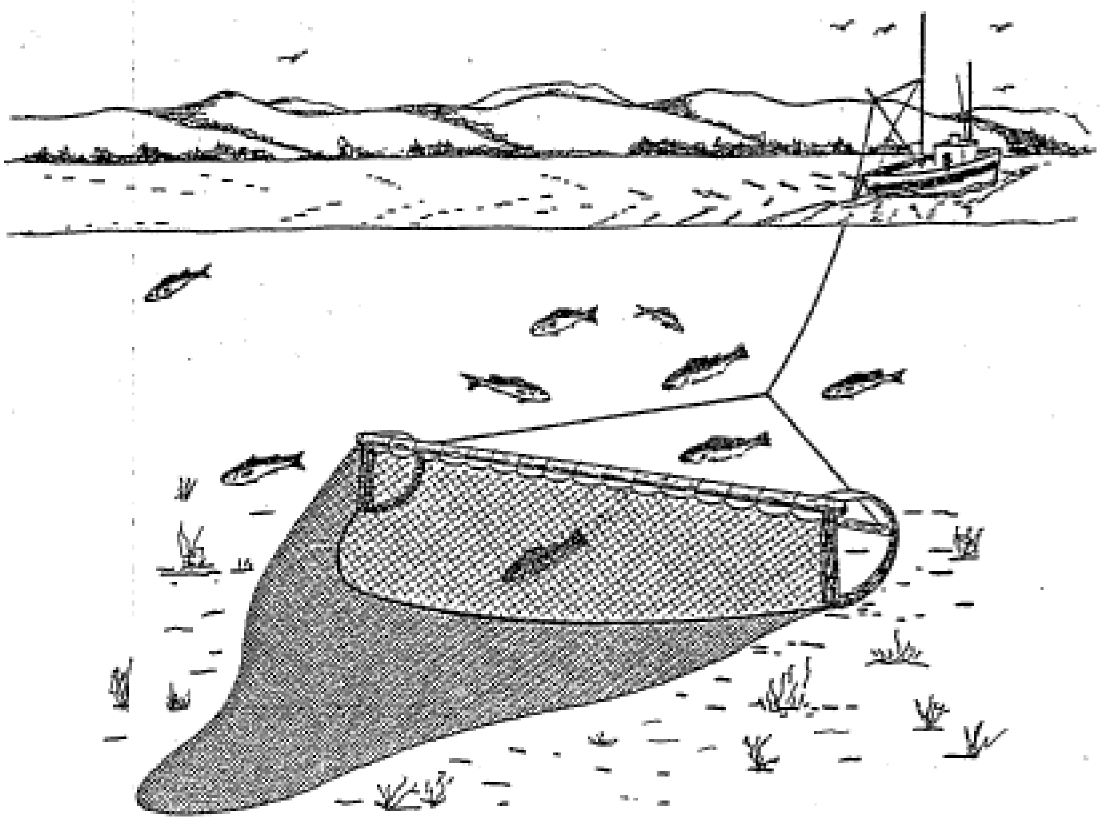

Figure 4. The Beam Trawl. Modified from Dumont and Sundstrom (1961).

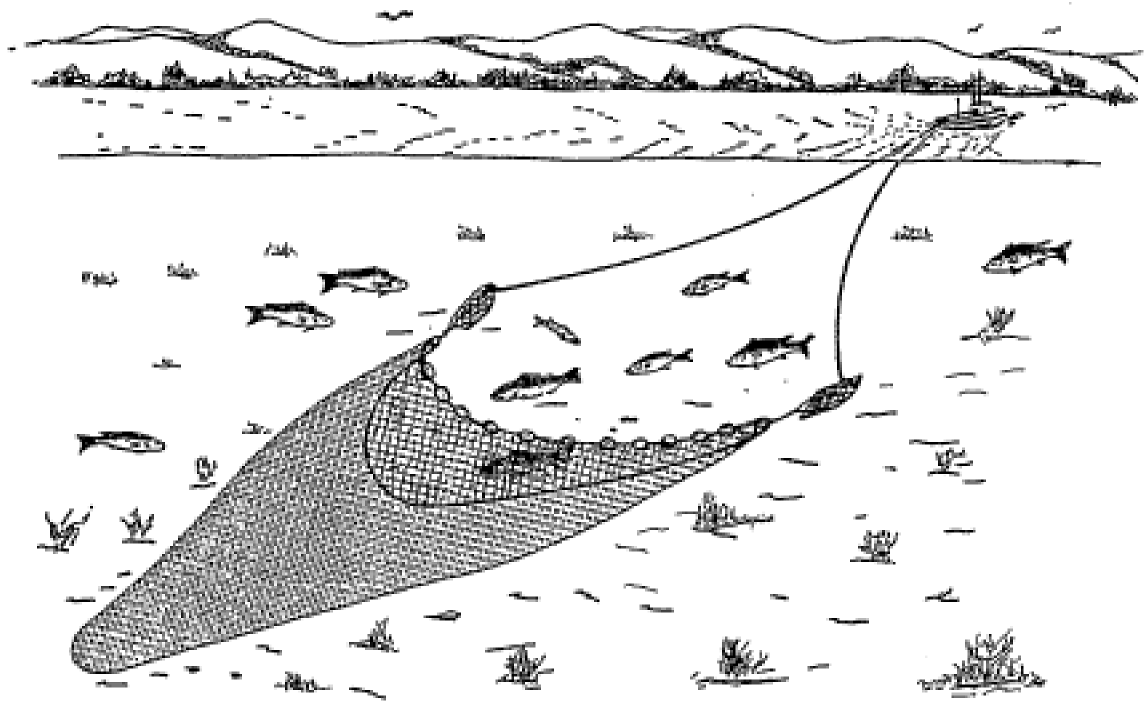

Figure 5. The Otter Trawl. Modified from Dumont and Sundstrom (1961).

4.2.2.5 Trawling data are usually expressed in weight numbers, species, etc.of catch per unit of time.

4.2 2.6 The use of trawls requires experienced personnel. Boats deploying large trawls must be equipped with power winches and large motors. Also, trawls can not be used effectively if the bottom is irregular or harbors snags or other debris. Trawls are used to gain information on a particular species of fish and an overally estimation of fish populations and communities. See Hayes (1983), Massman et al. (1952), Rounsefell and Everhart (1953), and Trent (1967) for further information on trawls.

4.2.2.7 In selected studies a plankton net may be used as a trawl. Larval and young fishes can be collected at the surface and bottom with a 1 meter plankton net by trawling a transect with a predetermined time frame (say ten minutes). A plankton sled can be used to hold a meter plankton net towed at the bottom while a sidearm can be used at the surface (Dovel, 1964). A digital flowmeter can be mounted in the mouth of the net to determine the amount of water strained. Large numbers of plankton can be collected in a short time by using a Miller high-speed sampler. Another sampler type, the bongo net, is a pair of nets held side-by-side in a frame and is towed by a cable that attaches to the frame between the two nets. Bongo nets are good because they can be used off ships at high speed, can be used to sample the horizontal layer of the water column, and can be used to get replicate samples at the same time.

4.2.2.8 The larval stage by some individuals is considered the period from time of hatching until the attainment of the adult fin-ray complement, ossification of spines or rays and the inception of scale development. Mansuetti and Hardy (1967) defined the "larval" stage as the period from the disappearance of the yolk sac until the development of the adult fin-ray complement.

4.2.3 Several companies sell a variety of fish nets, seines, traps, trawls, etc.:

1. Sterling Marine Products, 18 Label Street, Montclair, NJ 07042, Telelphone (201) 783-9800 or Jonesport, Maine 04649, Telephone (207) 497-5635

2. Nylon Net Company, 615 E. Bodley Avenue, P.O. Box 592, Memphis, TN 38101, Telephone (901) 774-1500, FAX (901) 774-8130.

3. Memphis Net and Twine Company, Inc., 2481 Matthews Avenue, P.O. Box 8331, Memphis, TN 38108, Telephone (901) 458-2656, FAX (901) 458-1601.

4. Nichols Net and Twine Company, Inc., R.R.3 Bend Road, East St. Louis, IL 62201, Telephone (618) 876-7700.

4.2.4 Horizontal Ichthyoplankton Tow-Net

4.2.4.1 The larval fish sampler (Figure 6) consists of a modified bridle, frame, and net system with an obstruction-free opening. The tow net is easy to handle, and it is small enough for use on boats 4 m or larger in length. The tow net features a square net frame attached to a 0.5 m diameter cylinder-on-cone plankton net with a bridle. This design eliminates all towing obstructions forward of the net opening; in addition, it significantly reduces currents and vibrations in the water directly preceding the net. See Subsection 4.2.4.2 for the design and construction details of the horizontal ichthyoplankton tow-net. With the aid of a stanchion and winch assembly, one person can easily sample any stratum from near surface to near bottom in lakes and rivers. The cylinder-on-cone net is self-washing while it is being fished, and only the last 20 cm needs to be rinsed to concentrate the sample in the collecting bucket. The system is self closing during deployment and retrieval. During deployment, the towing cable is payed out at approximately the same speed that the vessel is moving forward. This allows the weighted net to rapidly descend, with the net mouth in the vertical plan, while collapsing the net body and thus preventing the net from fishing. When the net has reached the desired fishing depth, the release of the towing cable is stopped and the net begins fishing (Figure 6). Prior to retrieval, the vessel is stopped, and the vertical orientation of the net mouth and rapid lifting causes the net body to collapse, preventing the net from fishing. Nester (1987) and Nester (1992, personal communication) reported that the tow net system is effective in collecting all lentic fish larval species at sampling depths ranging from surface to 10 m and can easily be used at greater depth.

4.2.4.2 The 6.3-mm galvanized steel towing cable (1) is connected to the center of the fore-bridle (2) with a 76.2-mm heavy duty snap swivel. A 25.4-mm thimble is permanently fixed with 3.2-mm cable clamps in the center of the 3.2-mm galvanized steel cable fore-bridle. The spreader bar (3) is constructed of 9.6-mm cold-rolled steel with two 38.8-mm clevises welded in place at either end. Side cable (4 and 5) of 3.2-mm galvanized steel are connected to the spreader bar clevises and to clevises welded to each corner of the net frame (6). The net frame is constructed of 9.6-mm cold-rolled steel heated, bent to form a 53-cm square, and closed by welding. Corner supports (7) provide additional strength and attachment points for netting. Two flowmeter support brackets (8a and 8b), to which flowmeters (9) are attached, are welded to the net frame and corner supports. Each bracket is bent at two 45° angles, so that the free end is about 5-cm behind the plane of the mouth of the net. Stainless steel support cable (10) is passed through a pair of 116-mm holes drilled 3-cm apart in the free end of the bracket to support the flowmeter. Nylon cord is used to lash the 0.5-m-diameter brass net ring (11) to the net frame and corner supports. The net bucket is secured to the cod end (bag end of a net) of the net with a hose clamp. Cables (12) supporting the 1-kg depressor plate (13) are attached to the lower corners of net frame with 3.2-mm cable clamps.

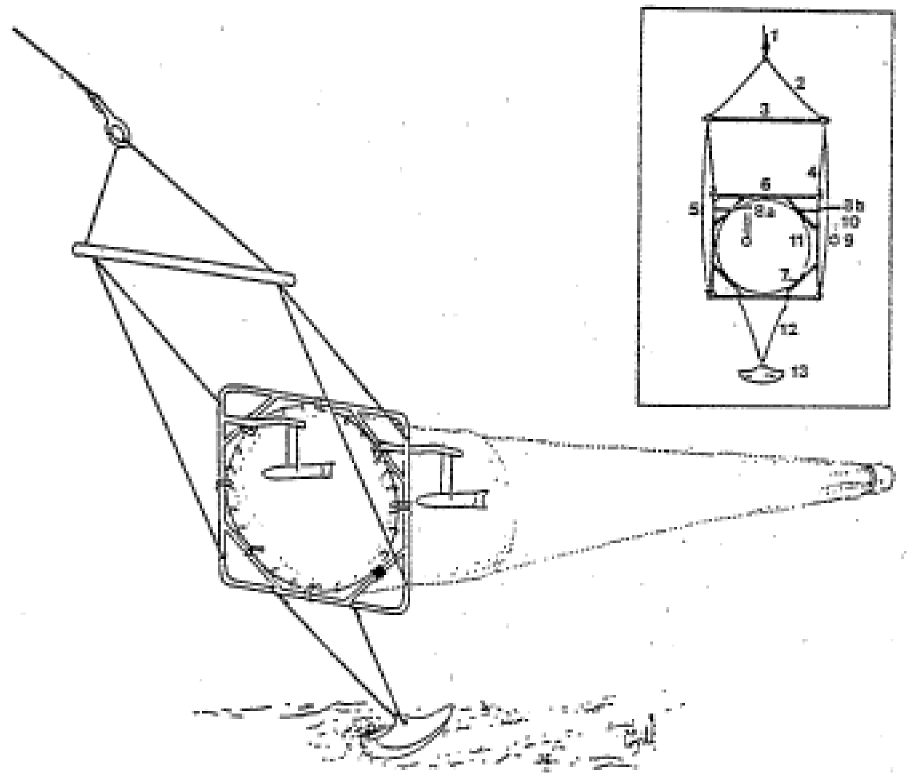

Figure 6. Horizontal Ichthyoplankton Tow-Net. Attitude of the modified bridle, frame, and net of the sampling system and diagram of the construction details. Numbers are referred to in Subsection 4.2.4.2. From Nester (1987).

4.2.4.3 The 0.5-m plankton net, a cylinder-on-cone configuration, is constructed of 0.335-mm mesh to the dimension given by O'Gorman (1984). A net of this type should have superior sustained filtration ability because of the high ratio of open mesh area to mouth area (6.3:1) and because oscillations of the cylindrical portion seemingly help clean the net during a tow (Tranter and Smith, 1968).

4.2.4.4 Commercial ichthyoplankton nets are available with threaded cod ends. Plastic cod end jars can be easily screwed into these and when the sample is finished being collected and preserved, a lid is screwed onto the jar and a new jar added to the net. These allow for rapid sample handling and decreased time. These have been found to be important if there are a lot of samples to be taken and numerous collecting sites.

4.2.4.5 Information on collecting and processing fish eggs and larvae are found in Simon (1989), Snyder (1983), and marine recommendations are provided by Smith and Richardson (1977).

4.3 Electrofishing

4.3.1 Electrofishing is an efficient capture method that can be used to obtain reliable information on fish abundance, length-weight relationships, and age and growth of fish in most streams of order 6 or less (Platts et al., 1983 and Plafkin et al., 1989). **Note:** Individuals involved in electrofishing must have completed a certified training course in electrofishing or have been trained by someone certified and experienced in electrofishing. This subsection provides some general principles and guidelines for understanding electrofishing. Electrofishing is a method for collecting fish using electricity. Either alternating (AC) or direct (DC) electrical current can be used. Most electrofishing in freshwater is done with pulsed DC electrical current equipment. In a boat-rigged shocker (boom shocker) or airboat, one or two people net the fish and another operates the boat and equipment. The fish are nearly always driven into cover as a result of electric stimulus making them difficult to capture. Once driven from cover, the fish are kept within effective range of the electrical field and are immobilized making it possible to pick them up with long-handled dip nets. Electrical dislodgement and immobilization of fish together result in more consistent success under varying conditions than ordinary seining. However, if target assemblage is common species, seining may be just as effective. For a discussion of the general principles and guidelines for electrical fishing, see below and Cowx (1990), Cowx and Lamarque (1990), Cross and Stott (1975), Dauble and Gray (1980), Elson (1950), Friedman (1974), Hartley (1980), Kolz (1989), Kolz and Reynolds (1989a, 1989b), Loeb (1955), Novotny and Priegel (1971, 1974), Ohio EPA (1987a, 1987b, 1989), Reynolds (1983), Sharpe (1964), U.S. Fish and Wildlife Service (1991), Vincent (1971) and Section 12, Fisheries Bibliography, 12.2 Electrofishing.

4.3.2 The decision to use electrofishing equipment (or electrofishers) will depend on size of site, flow, turbidity, and conductivity. If conductivity is below 100μS (micro seimens) or if water is too turbid to locate stunned fish, the investigators should consider other sampling devices (e.g., seines).

4.3.3 A choice of electrofishing equipment will depend on size of stream and access to stream from road. If a site is wadeable and close to the road, use Sportyak-mounted, generator unit or equivalent. If access is problematical, use a back pack unit. **For safety reasons, it is important too always wear waders and lineman's insulated (or Playtex Living) gloves when working with electricity in water.** At least two individuals for safety reasons (see Section 3, Safety and Health) are need when electrofishing. Always wear polarized sunglasses to aid vision.

4.3.4 Electrofishing efficiency can be placed in one of three categories: fish characteristics, habitat characteristics, and operating conditions. For a discussion of these three categories, see Reynolds (1983).

4.3.5 It is also recommended that anyone involved in electrofishing must take a U.S. Fish and Wildlife training course in electrofishing, or they must be trained by someone experienced in electrofishing.

4.3.6 Electrofishing Equipment (Electrofishers)

4.3.6.1 Electrofishing today is done by wading in shallow streams and using electric seines, backpacks, tow barges, longlines, etc. or in deep streams and rivers with electrofishing boats.

4.3.6.2 Typically a flat-bottom boat (usually 12 to 18 ft) is used for electrofishing in waters too deep for wading (Novotny and Priegel, 1974). Paired booms, (length vary according to boat size), protrude in front of the boat and are adjustable for height and spacing by means of lock-in adjustments. The electrode system should also be adjustable, i.e., operating with one or both anodes, varying the number of dropper electrodes, varying the exposure on the dropper electrodes, and alternating the polarity (Figure 7).

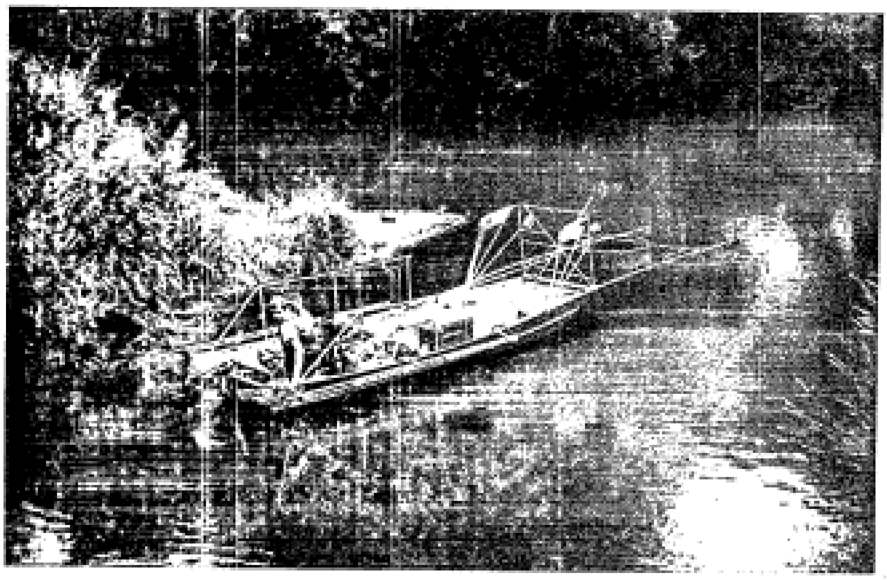

Figure 7. Typical Boom Shocker. Photo courtesy of Wisconsin Department of Natural Resources.

4.3.6.3 The electrofishing power unit may consist of a 240-volt or 500-volt, 2000 watt, heavy-duty generator and an electrical control section consisting of a modified, commercially-available, variable-voltage pulsator. The frequency of the cycles/second or Hz is not a critical factor. For AC electrofishing, 60, 180, and 400 Hz have been used with similar success. An electric control section permits the selection of AC voltage from 50-700 and DC voltage from 25 to 350; furthermore, it permits control of the electrical-field size which is dictated by the variable conductance of dissolved minerals in the water. The power equipment is similar in both boat shocking and stream shocking, but is portable in the latter. The literature indicates that DC electrofishing is the most comprehensive and effective, single method for collecting fish in rivers and streams (Gammon, 1973, 1976; Novotny and Priegel, 1974, and Ohio EPA, 1987b, 1989; Vincent, 1971).

4.3.6.4 Backpack electrofishers are entirely housed in a weatherproof metallic container that is fastened securely to a comfortable pack frame (Blair, 1958; Braem and Ebel, 1961; McCrimmon and Berst, 1963; Reynolds, 1983; Sharpe and Burkhard, 1969). Backpack shocker units can be purchased commercially. The power source is either a 12-volt (deep charge battery or a small 115-volt AC generator). The electrode system is hand-held and must be insulated from the operator by handles 1.5-3.0 m long, preferably made of fiberglass. A horizontal ring or spatula electrode attached to the end of the handle is easiest and most effective to use. Positively activated switches on each electrode handle are an important safety features. Both backpack, tote barge, and boat mounted shockers are available from U.S. manufacturers in a variety of models (see Subsection 4.3.13).

4.3.6.5 Other electrofishing devices include: tote barges/sport yaks (Ohio EPA, 1987b, 1989); longlines (Ohio EPA, 1987b); electric trawls (AC) (Haskell et al., 1955); and (Loeb, 1955); electric seines (Funk, 1947; Holton, 1954; Larimore, 1961; Bayley et al., 1989); and a fly-rod electrofishing device employing alternating polarity current (Lennon, 1961). After reviewing the literature, the user must decide which design is most suitable to the particular needs of the study.

4.3.6.6 Decision on the use of AC, DC, pulsed DC or alternate polarity forms of electricity and selection of the electrode shape, electrode spacing, voltage and proper equipment depends on the resistance, temperature and total dissolved solids in the water. Light-weight conductivity meters are recommended for field use. Lennon (1959) provides a comprehensive table and describes the system or combination of systems that worked best for him. Novotny and Priegel (1974) provide improved designs to increase the effectiveness of boom shockers.

4.3.6.7 Rollefson (1958, 1961) tested and evaluated AC, DC, and pulsated DC, and discussed basic electrofishing principles, wave forms, voltage-current relationships, electrode types and designs and differences between AC and DC and their effects in hard and soft waters. He concluded that pulsated DC was best for power economy and fishing ability when used correctly. Haskell and Adelman (1955) found that slowly pulsating DC worked best in leading fish to the anode. Pratt (1951) also found the DC shocker to be more effective than the AC shocker. Frankenberger (1960) and Latta and Meyers (1961) used a DC shocker, and Larimore et al. (1950) used AC current in boat shocking. Stubbs (1966) used DC or pulsed DC and had his aluminum boat wired as the negative pole.

4.3.6.8 Fisher (1950) found that brackish water requires much more power (watts) than freshwater even though the voltage drops may be identical. Lennon and Parker (1958) and Seehorn (1968) recommended the use of an electrolyte (salt blocks) when sampling in some soft waters to produce a large enough field with the electric shocker.

4.3.6.9 Novotny and Priegel (1974) provided operational guidelines to increase the effectiveness of boom shockers. They suggest that in the operation of DC or pulsed DC it is important that the electrofishing boat move much more slowly than in using AC. In general, AC operation is preferable at night in shallow clear water where visibility is no problem, and it is not necessary to attract fish from cover. Pulsed DC is effective in deep or turbid water where fish must be drawn from cover and collected by long-handled dip nets.

4.3.7 Areas considered as problems in boat electrofishing are (Novotny and Priegel, 1974):

4.3.7.1 Range limitations (distance at which fish are affected).

4.3.7.2 Water conductivity (difficulty in attaining sufficient current in water of low conductivity.

4.3.7.3 Bottom materials (reduces effectiveness of electrofishing by highly conductive bottom material).

4.3.7.4 Water depth (difficulty capturing immobilized fish at depths beyond 0.9 - 1.2 m) due to visibility, length of dipnet handle, etc.

4.3.7.5 Water clarity and vegetation (these factors restrict visibility).

4.3.7.6 Water temperature (best response depends on the species and water temperature).

4.3.7.7 Fish mortality (much higher with AC electricity than DC or pulsed DC).

4.3.7.8 Fish size (selectivity of size) is not much of a problem with modern electrofishing units.

4.3.7.9 Fish species (selectivity for species-swimming ability).

4.3.7.10 Equipment and operating problems (inadequate lighting, power, voltage controls, instrumentation, electrode design, etc.).

4.3.7.11 Day and night sampling (some species sampled better during the day than night and vice versa) (Sanders, 1991; 1992).

4.3.7.12 Novotny and Priegel (1974) were able to overcome many of the above problems. These same problems are also encountered in stream electrofishing (Novotny and Priegel, 1971).

4.3.8 Safety

4.3.8.1 In order for electricity to flow, electricity needs a complete electrical circuit, moving from the anode to the cathode. Therefore, the only way an individual can get shocked is if they become part of the circuit. During electrofishing, the water becomes the connection that completes the circuit between the anode and the cathode. You must, therefore, be electrically insulated from the water and the electrodes of the electroshocker (electrofisher). Otherwise, you become part of the circuit and will get a shock.

4.3.8.2 Novotny and Priegel (1974) and Ohio EPA (1989, 1990) give a complete description of an electrical safety disconnect system and discuss electrical safety and safety regulations. An 18 foot boat provides a greater margin of safety in rough water, and a safety railing surrounding the front deck and extending along each side of the boat affords protection of the operators against the hazard of falling over-board into the electric field near the boat.

4.3.8.3 Floor mat switches or foot pedals with non-skid surfaces should be permanently installed on the front deck. Thus, each operator must be in position before the system is energized. Likewise, a throw switch should be installed on the rear seat for the outboard motor operator.

4.3.8.4 When metal booms are used an electrical ground wire terminated with a battery clamp should be provided to assure a positive electrical ground for each boom.

4.3.8.5 All electrical circuits should be enclosed in metal conduit with a separate conduit system for the main power (high voltage) circuits, auxiliary power and safety circuits (low voltage). Watertight junction boxes should be used throughout the electrical system.

4.3.8.6 Because the nets used to capture fish must be dipped into the water near the electrodes, it is very important that the net handles be constructed of materials with good electrical insulating properties. Epoxiglass insulating materials used on electricians tools are the best material. Fiberglass covered metal can cause accidents if the fiberglass covering is damaged, allowing contact between the operator and the metal handle. The operator must wear rubber gloves.

4.3.8.7 All leads associated with the generator are carefully insulated. Generally, AC or DC, used in electrofishing provides more than enough voltage and current to shock and electrocute a person.

4.3.9 In a boat shocking operation the following safety precautions should be observed:

4.3.9.1 Wear U.S. Coast Guard approved life jackets.

4.3.9.2 Wear felt sole neoprene waders or hip boots and insulated arm length gloves.

4.3.9.3 Avoid excess fatigue and be constantly alert.

4.3.9.4 Authorize one person to be in charge.

4.3.9.5 Instruct all personnel in the fundamentals of electricity.

4.3.9.6 Thoroughly familiarize all persons with all phases of the equipment and its operation.

4.3.9.7 Make sure that all equipment is in good condition and properly used.

4.3.9.8 Make sure that there is a first aid kit and fire extinguisher on the boat.

4.3.9.9 Know how to administer first aid treatment for electrical shock.

4.3.9.10 Never operate electrofishing equipment if you have any prior heart ailment.

4.3.10 The following things must be done to prevent electrical shock when using electrofishing equipment:

4.3.10.1 Use water-tight, preferably chest or waist-high, waders (neoprene waders with felt-sole boots). If the waders or wading boots become wet inside, stop electrofishing and let them dry out thoroughly before electrofishing again. Wet wading boots can conduct electricity.

4.3.10.2 Use water-tight lineman's insulated gloves that cover up to at least

the elbows. If they get wet inside, stop electrofishing and let them dry out completely before continuing electrofishing.

4.3.10.3 The individual doing the electrofishing must take care not to let the anode come into contact with anyone while the unit is active. In addition, one must make sure and be aware that anyone in or near the water is electrically insulated with wading boots and gloves.

4.3.11 Electrofishing procedures for use in wadable streams

4.3.11.1 The sampling gear should consist of backpack electrofishing equipment supplemented by block netting and seining in habitats where flow, substrate, and structure affect capture of benthic fish species.

4.3.11.2 The investigator(s) should follow project plans, standard operating procedures (SOPs), and safety for electrfishing in wadable streams and rivers.

4.3.11.3 Decision to use electrofishing equipment will depend on size of site, flow, and turbidity. If flow is too high, site to deep, or water too turbid to locate stunned fish, the investigators may consider use of seine only. This is a safety decision.

4.3.11.4 Once the sampling site has been located, determine the fish sampling reach as a function of mean channel width taken at the site (20-30 channel widths). The sampling site may serve as the midpoint of the sample reach. The investigator should walk the length of the sample site to determine pool depths, habitat composition, barriers, and obstructions which may impede or aid in fish capture. Also, determine if reach requires block nets be placed at upstream and downstream ends of the stream (e.g., where sample reach is a large continuous pool).

4.3.11.5 Set the electrofishing unit to 300 VA and pulsed DC. Based on stream conductivity, select initial voltage setting. Determine that all crewmembers are wearing waders, gloves, are clear of the anode. Start generator, set timer, and depress switch to begin fishing. Starting at the bottom of the most downstream riffle, pool, or other habitat type in the sampling reach, fish in an upstream direction, parallel to the current. Adjust voltage and waveform output according to sampling effectiveness and incidental mortality to specimens. Voltage gradients of 0.1 to 1.0 volts/cm are effective for stunning fish. These gradients can be maintained in freshwater of normal conductivity (100-500 micromhos/cm) by adjusting circuit voltage to produce a current of 3-6 amperes (Reynolds, 1983).

4.3.11.6 With switch depressed, sweep electrodes from side to side in the water in riffles and pools. Sample available cut-bank and snag habitat as well as riffles and pools.

4.3.11.7 Netters follow along behind person operating shocker and net stunned fish which are then deposited in separate buckets or holding tanks based on habitat from which fish are collected. Minnow seines (4 m x 2 m x 0.5 cm) and kick nets (2 m x 2 m x 0.5 cm) may be used to block in riffles, polls, and snags.

4.3.11.8 Depending on the study design, fish may be collected according to time and distance criteria. The collection time should be no less than 45 minutes and no greater than 3 hours for a distance of between 150 - 500 m in order to obtain replicate samples from two riffles and two pools, or in the absence of discrete habitat types, a segment of at least 200 m of stream has been sampled. Homogeneous (or large systems) without clearly defined habitat types should be sampled wherever best fish habitat is found. Distance sampled should not exceed 500 m. Record total time spent collecting.

4.3.11.9 Record all information on field data sheets. Sport fish, large specimens and threatened and endangered species should be identified in the field, measured (standard length, total length, body depth), examined for external anomalies, and released unharmed. All other specimens should be preserved in 10% formalin solution (see Section 5, Specimen Processing Techniques) and kept in separate jars by habitat type with inner and outer waterproof labels. Labels should contain locality data, habitat type, date, collectors names, and study collection numbers from the field sheets for that site.

4.3.12 Standard operating and safety procedures for commercial shocker boat should be followed in boatable streams and rivers.

4.3.13 Companies that sell a variety of electroshocking equipment (electrofishing boats, boat outfitting electrofishing kits, electrofishing tote barges, backpack electrofishing units, electrofishers, etc.):

1. Coffelt Manufacturing, Inc., P.O. Box 1059, Flagstaff, AZ 86002 or 1311 E. Butler Avenue, Building B, Flagstaff, AZ 86011, Telephone (602) 774-8829

2. Smith-Root, Inc., 14014 N.E. Salmon Creek Avenue, Vancouver, WA 98686, Telephone (206) 573-0202

4.4 Chemical Fishing (Ichthyocides)

4.4.1 Fish toxicants for sampling fish populations are a common practice in impounded waters and streams throughout the United States. Only registered fish chemical toxicants should be used in collection fish populations. The Federal and State rules should be check prior to use because they continually are updated and subjected to change. The decision to use a chemical toxicant should be based not only on the efficacy of the toxicant, but also on its persistence in the environment, toxicity to other animals, and whether it is deleterious to man. Fish toxicants for reclamation are thoroughly reviewed by Lennon et al. (1971), and papers addressing their use in sampling are found throughout the literature. Additional information on sampling fish populations with toxicants is found in APHA (1992), ASTM (1992), Bone (1970), Boccardy and Cooper (1963), Davies and Shelton (1983), Hocutt et al. (1973), Hooper (1960), Marking (1992), Meyer et al. (1976), Platts et al. (1983), Schnick (1974), Schnick and Meyer, (1978), and Section 12, Fisheries Bibliography, Subsection 12.3, Chemical Fishing.

4.4.2 Chemicals used in fish sampling include rotenone, cresol, copper sulfate, antimycin A, and sodium cyanide. The ideal ichythocide indicated by Hendricks et al. (1980) is (1) nonselective; (2) easily, rapidly, and safely used; (3) readily detoxified; and (4) not detected and avoided by fish.

4.4.3 When using an ichthyocide, care must be taken to ensure that it will be used correctly and approval for use must be obtained from proper Federal and State authorities. Hendricks et al. (1980) reported that improper application of rotenone can have disastrous effects downstream.

4.4.4 Rotenone (Derris or Cube roots) has generally been the most acceptable because of its high degradability, freedom from such problems as precipitation (as with copper sulfate), and relative safety for the user.

4.4.5 Pesticides, copper sulfate, cresol, and other chemicals have been used as fish toxicants, but they are toxic to humans, may add taste or odor to the water, have a slow rate of detoxification, may be toxic to other organisms, and, therefore, should not be used for sampling purposes.

4.4.6 Antimycin A has been registered by the Governments of the United States and Canada as a fish toxicant since 1966. The dry formulation is known as "Fintrol" and has been registered by a commercial company. Field trials have been made and reported by the U.S. Fish and Wildlife Service. Successful usage has been reported over a wide range of water qualities and water temperatures. It is effective on fish at concentrations of 1 part per billion and less but is reported to be relatively harmless to plants, insects, mammals, and birds.

4.4.7 Rotenone is also registered for fishery use by the U.S. Environmental Protection Agency according to the Federal Environmenal Pesticide control Act (Schnick and Meyer, 1978). Rotenone, obtained from the derris root (*Deguelia elliptica*, East Indies) and cube root (*Lonchocarpusw nicour*, South America) in the family Leguminosae, has been used intensively in fisheries work throughout the United States and Canada since 1934 (Krumholz, 1948). Rotenone kills fish by blocking oxygen uptake, and the fish suffocate. The toxicity of Rotenone is a function of the species, size of fish, and water temperature. The pH, dissolved oxygen, and suspended particulate matter in the water can also affect its toxicity. It is effective in a short time period. Also, it has low toxicity to birds and mammals (Hendricks et al., 1980). Davies and Shelton (1983) reports that Rotenone at concentrations of 1.0 to 2.0 mg/L is lethal to zooplankton and many aquatic invertebrates, but the effects is short term. Although toxic to man and warm-blooded animals (132 mg/kg), rotenone has not been considered hazardous in the concentrations used for fish eradication (0.025 to 0.050 ppm active ingredient) (Hooper, 1960), and has been employed in waters used for bathing and in some instances in drinking water supplies (Cohen et al., 1960, 1961). Adding activated carbon in the water treatment process not only effectively removes rotenone, but also removes the solvents, odors, and emulsifiers present in all commercial rotenone formulations.

4.4.8 Rotenone obtained as an emulsion containing approximately 5% active ingredient, is recommended because of the ease of handling. It is a relatively fast acting toxicant. In most cases, the fish will die within 1 to 2 hours after exposure. Rotenone decomposes rapidly in most lakes and ponds and is quickly dispersed in streams. In warm water lakes or streams at summer water temperatures, toxicity lasts 24 hours or less. In cold water lakes toxicity may last for 5 to 30 days. Detoxification is brought about by five principal factors: dissolved oxygen, light, alkalinity, heat, and turbidity. Of these, light and oxygen are the most important factors.

4.4.9 Although the toxicity threshold for rotenone differs slightly among fish species, it has not been widely used as a selective toxicant. It has, however, been used at a concentration of 0.1 ppm of the 5% rotenone emulsion to control gizzard shad (Bowers, 1955). For most species the toxicity of rotenone is greatest between 10°C (50°F) and 23.9°C (75°F), and a 0.5 mg/L of formulation (0.025 mg/L of rotenone) kills most fish species. The toxicity drops as temperature decreases. Formulation of 1.0 to 2.0 mg/L is usually used to insure a complete kill, and blocking nets should be used in the sampling area to ensure the desired catch. Sensitivity to rotenone varies considerable among species and among life stages within a species (Holden, 1980). The toxicity is affected by temperature, pH, oxygen concentration, and light (Hendricks et al., 1980; Holden, 1980). USEPA (1978) recommends a concentration of 0.1 mg/L for sensitive species, and a concentration of 0.7 mg/L is recommended if bullheads and carp are present.

4.4.10 Chemical sampling is usually employed on a spot basis, e.g., a short reach of river or an imbayment of a lake or reservoir. A concentration of 0.5 ppm active ingredient (1/2 gal. 5% rotenone/acre ft.) will provide good recovery of most species of fish in acidic or slightly alkaline water (Table 4). If bullhead and carp are suspected of being present, a concentration of 0.7 ppm active ingredient is recommended. If the water is turbid and strongly alkaline and resistant species (i.e., carp and bullheads) are present, use 1-2 ppm. However, caution is advised because rotenone dispersed into peripheral water areas may kill fish as long as the concentration is above 0.1 ppm. When rotenone is used in an embayment, some sort of blocking system should be in place to prevent fish in the area from escaping. Block seines or divers have been successfully used in past studies. Chemical blocks can be used but are recommended only when nets or divers cannot be successfully employed.

4.4.11 A very efficient method of applying emulsion products to lake waters and embayments is to pump the emulsion from a drum mounted in the bottom of a boat. The drum should be equipped with an outside tube, mounted on the drum and calibrated to indicate how fast the chemical is being pumped out of the barrel. The emulsion is suctioned out by a venturi pump (Amundson Boat Bailer) clamped on the outboard motor. The flow can be metered by a valve at the drum hose connection. This method gives good dispersion of the chemical and greater boat handling safety since the heavy drum can be mounted in the bottom of the boat rather than above the gunwales as required for gravity flow.

4.4.12 If spraying equipment is used, it will vary according to the size of the job. For small areas of not more than a few acres a portable hand pump ordinarily used for garden spraying or fire fighting is sufficient. Some individuals have successfully used a back-pack fire pump to collect fish samples from small streams or sections of streams. A mixture of one quart rotenone in five gallons of water is applied in small amounts.

4.4.13 A power-driven pump is recommended for a large-scale or long-term sampling program. The capacity of the pump need not be greater than 200 L per minute. Generally, a 1-1/2 h.p. engine is adequate. The power application of rotenone emulsives requires a pressure nozzle, or a spray boom, or both, and sufficient plumbing and hose to connect with the pump. The suction line of the pump should be split by a "y" to attach two intake lines. One line is used to supply the toxicant from the drum, and the other line to supply water from the lake or embayment. The valves are adjusted so that the water and toxicant are drawn into the pumping system in the desired proportion and mixed. A detailed description of spraying equipment can be found in Mackenthun (1969); Mackenthun and Ingram (1967).

4.4.14 A drip method is generally used to dispense rotenone to a flowing system. Select a 30 to 100 meter reach depending on the depth and width of the stream; measure the depth of the section selected, calculate the area and flow and determine the amount of chemical required (Table 5). Block off the area upstream and downstream with seines. Position containers of liquid rotenone at the upstream end of the stream reach to be sampled. Nozzles on the containers must be metered to deliver the predetermined amount of rotenone to the stream. For additional details concerning the use of a delivery system for the drip method and nomographs for calculating the amount of toxicant refer to Price and Haus (1963) and Davies and Shelton (1983). The toxic effect of rotenone can be eliminated almost immediately with potassium permangate ($KMnO_4$) at 1 mg/L for each 0.05 mg/L of rotenone (Lawrence, 1955, 1956; Davies and Shelton, 1983). In lentic waters, the potassium permangate needed to oxidize rotenone is equal to the amount of rotenone applied plus the chlorine demand of the water. In lotic waters the amount has been estimated as 2.5 mg/L per cubic foot per second during the entire time the rotenone is passing through the neutralization point (Platts et al., 1983). Also, potassium permangate is considered toxic to some fish species at 3 ppm. Potassium permanganate is also hazardous to apply, and nose, throat, and eye protection should be exercised by anyone working with it.

4.4.15 The following company sells aquaculture, quality manufactured drugs, chemicals, biological, scientific supplies, and fish farming equipment:

Argent Laboratories
9702 152nd Avenue Northeast
Richmond, WA 98052, Telephone (206) 885-3377

4.5 Hook and Line

4.5.1 Fish collection by hook and line can be as simple as using a hand-held rod or trolling baited hooks or other lures, or it may take the form of long trot lines or set lines with many baited hooks. In generally, the hook and line method is not acceptable for conducting a fishery survey, because it is too highly selective in the size and species captured and the catch per unit of effort may be low. Although it can only be used as a supporting technique, it may be the best method to obtain a few adult specimens for contaminant analysis, etc., when sampling with other gear is impossible.

4.5.2 A variation of this is "jug fishing" where a short drop line of 2-3 feet with a baited hook is attached to a jug or can and allowed to drift downstream. This is a particularly effective way of sampling catfish.

4.6 Passive Sampling Techniques

4.6.1 Passive sampling devices and techniques (Hubert, 1983) can be used to supplement boat electrofishing data in lakes, reserviors, large rivers, estuaries, marshes, and wetlands. Fyke nets and trap nets are used in shallow water while modified hoop nets and gill nets are used in deep or open waters All passive sampling techniques should be checked and emptied 12 to 24 hours after setting. Data collected by passive sampling techniques can be used to determine relative abundance which are expressed as number/24 hours and weight (kg)/24 hours (Ohio EPA, 1989).

TABLE 4. AMOUNT OF 5% EMULSIFIABLE ROTENONE EQUIVALENT TO 0.5 PPM OR 1.0 PPM PER ACRE-FEET OR POND OR LAKE TO BE SAMPLED

Rotenone (5% Emulsifiable) Application Rates		
Acre-Feet	Pints of 5% Rotenone 0.5 ppm	1.0 ppm
0.25	0.3	0.6
0.50	0.6	1.2
0.75	1.0	2.0
1.00	1.3	2.6
1.25	1.6	3.2
1.50	2.0	4.0
1.75	2.3	4.6
2.00	2.6	5.2
2.25	3.0	6.0
2.50	3.3	6.6
2.75	3.6	7.2
3.00	4.0	8.0
3.25	4.3	8.6
3.50	4.6	9.2
3.75	5.0	10.0
4.00	5.3	10.6
4.25	5.6	11.2
4.50	6.0	12.0
4.75	6.3	12.6
5.00	6.6	13.2
5.25	7.0	14.0
5.50	7.3	14.6
5.75	7.6	15.2
6.00	8.0	16.0

TABLE 5. CUBIC CENTIMETERS (cc) OF LIQUID ROTENONE PER MINUTE FOR GALLONS OF FLOW PER MINUTE

Flow of Stream in Gallons per Minute	Five Percent (5%) Liquid Rotenone Requirements in Cubic Centimeters Per Minute			
	0.5 ppm	1.00 ppm	1.5 ppm	2.0 ppm
10	0.019	0.038	0.057	0.076
20	0.038	0.076	0.114	0.151
30	0.057	0.114	0.170	0.227
40	0.076	0.151	0.227	0.303
50	0.095	0.189	0.284	0.379
60	0.114	0.227	0.341	0.454
70	0.132	0.265	0.397	0.530
80	0.151	0.303	0.454	0.606
90	0.170	0.341	0.511	0.681
100	0.189	0.379	0.568	0.757
200	0.379	0.757	1.136	1.514
300	0.568	1.136	1.703	2.271
400	0.757	1.514	2.271	3.028
500	0.946	1.893	2.839	3.785

4.6.2 Entanglement nets

4.6.2.1 Gill and trammel nets are used extensively to sample fish populations in estuaries, lakes, reservoirs, and larger rivers.

4.6.2.2 A gill net is usually set as an upright, vertical fence of netting and can have either a variable or uniform mesh size. Experimental gill nets made of monofilament may be 37.5 m long and constructed with 7.5 m panels of 15.2 mm, 22.9 mm, 25.4 mm, 40.6 mm, and 50.8 mm bar mesh, and the variable mesh size gill nets are generally preferred. Fish attempt to swim through the net and are caught in the mesh (Figure 8). Because the size of the mesh determines the species and size of the fish to be caught, gill nets are considered selective. The most versatile type is an experimental gill net consisting of five different mesh size sections. Mesh sizes depend on the size range of fish species to be sampled. A range of mesh sizes in an experimental gill net is used to obtain samples of several year classes of a single species, and it will also provide a greater chance to increase the number of species caught. Gill nets made of multifilament or monofilament nylon are recommended. Multifilament nets cost less and are easier to use, but monofilament nets generally capture more fish. The floats and leads usually supplied with the nets can cause net entanglement. To reduce this problem replace the individual floats and float line with a float line made with a core of expanded foam and use a lead-core leadline instead of individual lead weights and lead line. Gill nets are usually set in open waters to sample fishes in large rivers, lakes, and reservoirs. They can be set at the surface, mid-depth, or on the bottom depending on the objectives of the study and target species within the fish community. Gill nets should be anchored and marked well in open water areas with floats on both ends.

4.6.2.3 The trammel net (Figure 9) has a layer of large mesh netting on each side of loosely-hung, smaller gill netting. Small fish are captured in a "bag" of the gill netting that is formed as the smaller-mesh gill netting is pushed through an opening in the larger-mesh netting. Trammel nets are not used as extensively as are gill nets in sampling fish.

4.6.2.4 Trammel nets can be fished in all types of habitats found in rivers such as the Mississippi. If a backwater or quiet stretch of the river is to be fished, the net is set. If the river channel is to be fished, the net is floated or drifted downstream. Trammel nets are very efficient for taking such fish as carp and buffalo. Trammel net float fishing is an excellent method of sampling shovelnose sturgeon and freshwater drum.

4.6.2.5 Stationary gill and trammel nets are fished at right angles to suspected fish movements (e.g., parallel to shore) and at any depth from the surface to the bottom. They may be held in place by poles or anchors. The anchoring method must hold the net in position against any unexpected water movements such as, runoff, tides, or seiches.

4.6.2.6 Drifting gill or trammel nets are also set and fished the same as stationary gear, except that they are not held in place but are allowed to drift with the current. This method requires constant surveillance when fishing. They are generally set for a short period of time. If currents are too great, stationary gear may be used, but heavy current can cause the net to collapse.

4.6.2.7 Results for both trammel and gill nets are expressed as the number or weight of fish taken per length of net per day (=catch per unit effort).

4.6.2.8 The use of gill nets in estuaries may present special problems, and consideration should be given to tidal currents, predation, optimum fishing time, and types of anchors, floats, and line. When gill net fishing in tidal waters, it is recommended that reversing anchors be used for anchoring if the nets are to be left unattended. Mushroom anchors and concrete blocks will not hold down the nets during tidal cycles and may allow them to move considerable distances if a high tidal cycle is present. The gill nets should be monitored frequently and usually after a tidal cycle change as marine species usually will not survive too long in gill nets. Dead fish tend to attract crabs which tangle in the nets making them difficult to remove. When nets are set in the mouths of creeks, the outgoing tidal cycle generally will be more productive.

4.6.2.9 In freshwater, monofilament gill nets are very effective for lake herring, trout, lake whitefish, yellow perch, walleyes, and northern pike.

4.6.2.10 Necessary equipment for netting includes a pair of "clipper" pliers for removing sharp pectoral and dorsal spines on catfish and bullheads when these fish become tangled in the netting. Also, the gunnels of any boat used in a net fishing operation should be free of rivets, cleats, etc. on which the net can snag.

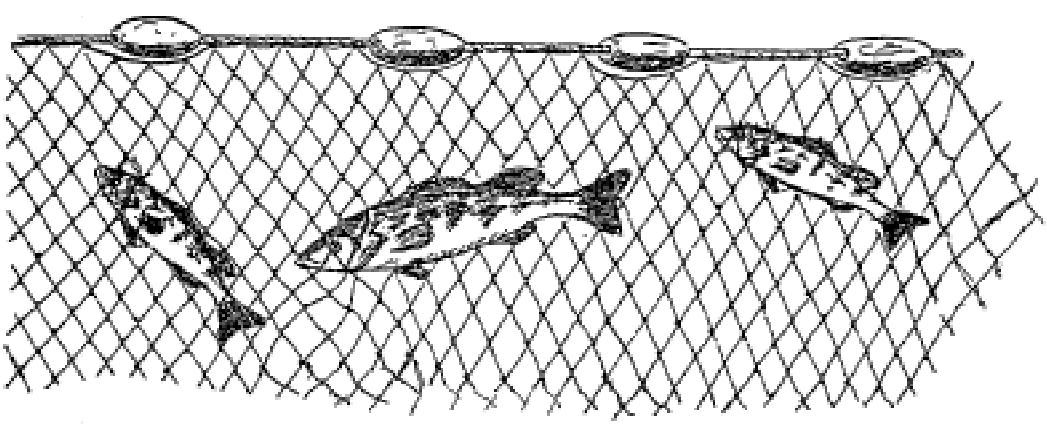

Figure 8. Gill net. Modified from Dumont and Sundstrom (1961).

4.6.3 Entrapment Devices

4.6.3.1 With entrapment devices, the fish enter an enclosed area (which may be baited) through a series of one or more funnels and prevent excapement. They are used to sample reserviors and wide river channels with slow velocity conditions. Entrapment nets are set in structurally complex areas where fish movement and density are anticipated to be highest in order to maximize net catches.

4.6.3.2 The hoop nets (modified hoop nets) and trap nets are the most common types of entrapment devices used in fishery surveys. These traps are small enough to be deployed from a small open boat and are relatively simple to set. They are held in place with anchors or poles and are used in water deep enough to cover the nets, or to a depth up to 4 meters.

4.6.3.3 The hoop net (Figure 10) is constructed by covering hoops or frames with netting. It has one or more internal funnels and does not have wings or a lead. The first two sections can be made square to prevent the net from rolling in the currents.

4.6.3.4 The fyke net (Figure 11) is a hoop net with wings, or a lead, or both attached to the first frame. The second and third frames can each hold funnel throats, which prevent fish from escaping as they enter each section. The opposite (closed) end of the net may be tied with a slip cord to facilitate fish removal.

4.6.3.5 Hoop nets are fished in rivers and other waters where fish move in predictable directions, whereas the fyke net is used when fish movement is more random such as in lakes, impoundments, and estuaries. Hoop and fyke nets can be obtained with hoops from 2 to 6 feet (0.6 to 1.8 meters) in diameter, but any net over 4 feet (1.2 meters) in diameter is too large to be used in a fishery survey.

4.6.3.6 Trap nets use the same principle as hoop nets for capturing fish, but their construction is more complex. Floats and weights instead of hoops give the net its shape. The devices are expensive, require considerable experience, and are usually fished in waters deep enough to cover them.

4.6.3.7 One of the traps which has proven to be quite effective is a 3 x 6 foot frame with a 3 x 50 foot lead consisting of 1/2 inch square mesh of #126 knotless nylon. Traps with 1/4 inch mesh netting have also been used. Trap nets are set with the lead perpendicular to the shoreline. They usually are most effective in depths less than 25 feet with a minimum depth of about 3 feet.

4.6.3.8 One of the most simple types is the minnow trap, usually made of wire mesh or glass, with a single inverted funnel. The bait is suspended in a porous bag. A modification of this type is the slat trap (Figure 12); this employs long wooden slats in a cylindrical trap, and when baited with cheese bait, cottonseed cake, etc., is usually very successfully in sampling catfish in large rivers.

4.6.3.9 Most fish can be sampled by setting trap and hoop nets of varying sizes in a variety of habitats. Hoop and trap nets are made of cotton or nylon, but nets made of nylon have a longer life and are lighter when wet. Protect cotton and nylon nets from decay by using the same methods of treatment mentioned for seines in Subsection 4.2.1.5. The catch is recorded as numbers or weight per unit of effort, usually fish per net day.

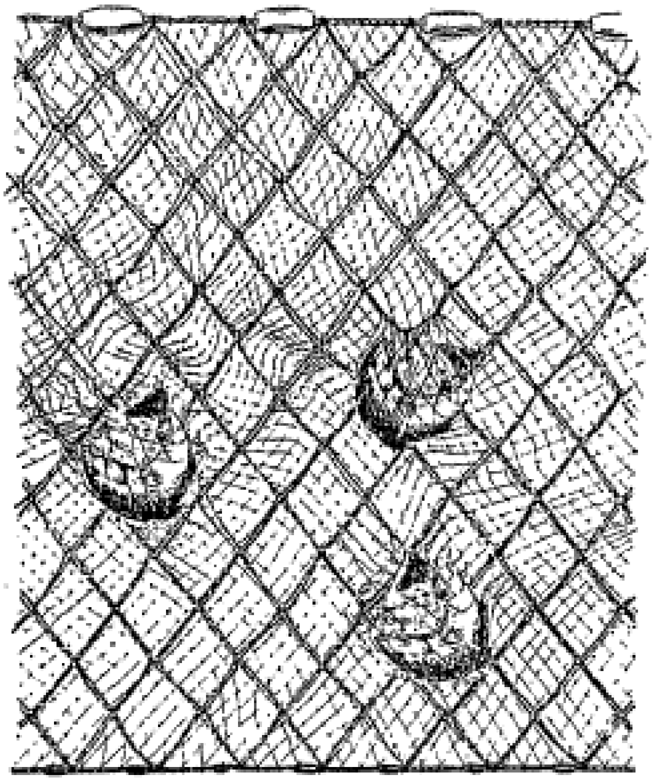

Figure 9. Trammel Net. Modified from Dumont and Sundstrom (1961).

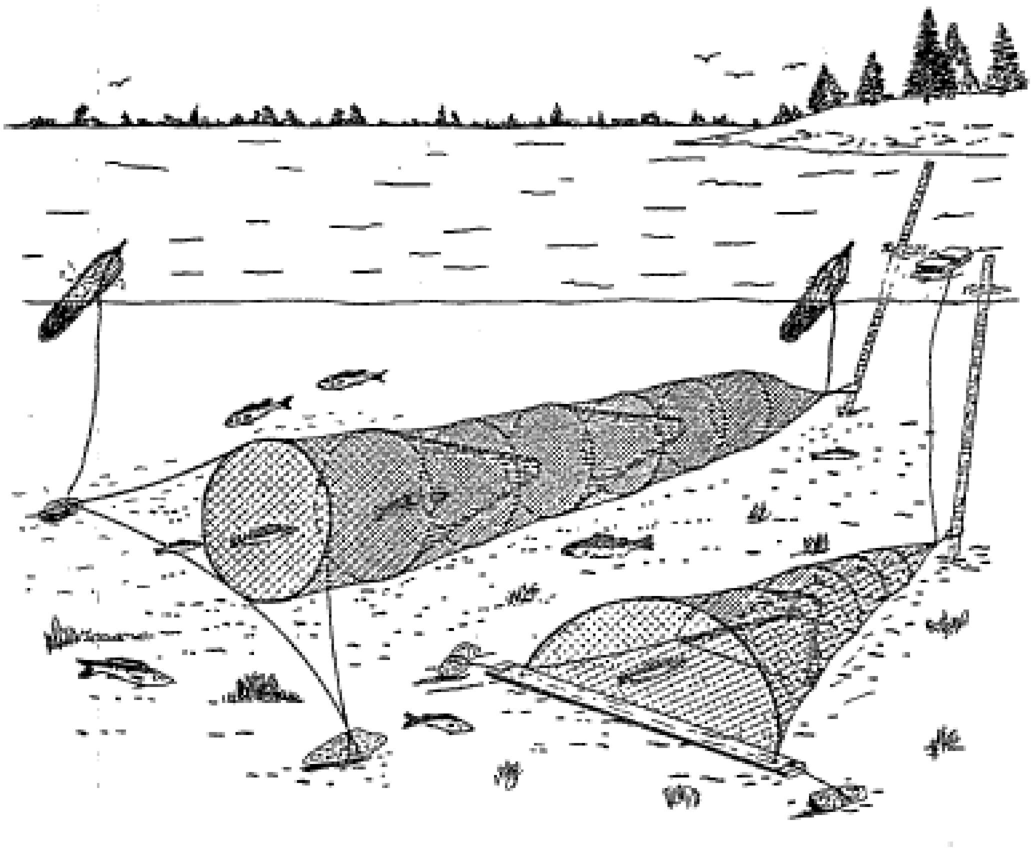

Figure 10. Hoop Nets. Modified from Dumont and Sundstrom (1961).

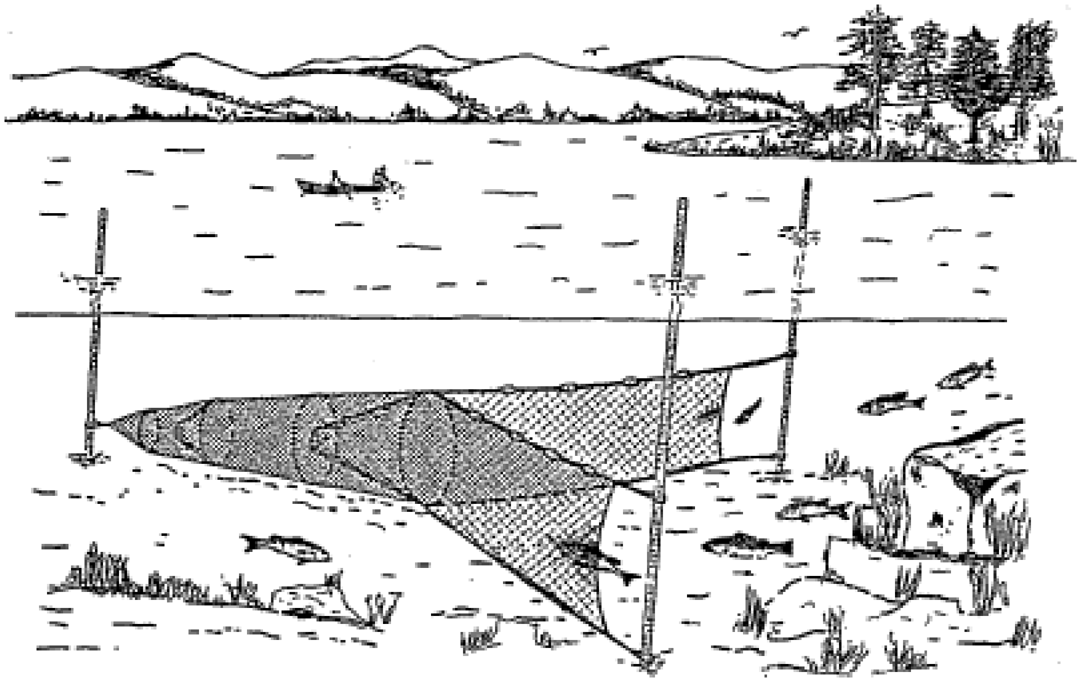

Figure 11. Fyke Net. Modified from Dumont and Sundstrom (1961).

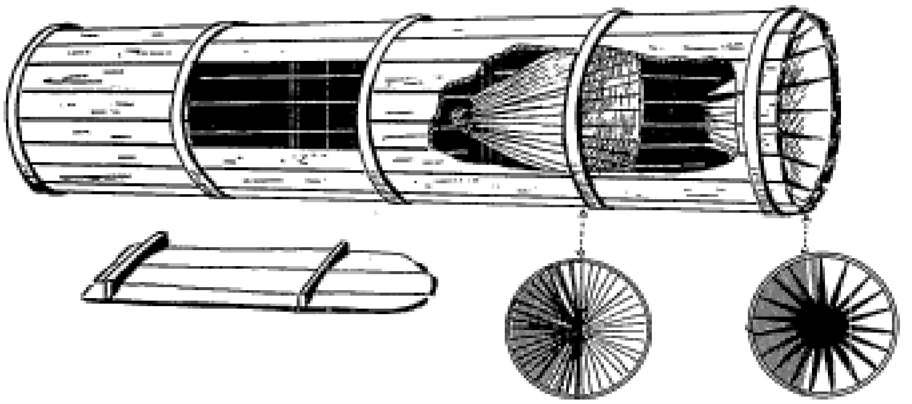

Figure 12. Slat Trap. Modified from Dumont and Sundstrom (1961).

4.7 Pop Nets

4.7.1 Pop nets are useful for sampling fish in shallow riverine waters in heavily vegetated and nonvegetated areas where seining or electroshocking may be difficult (Larson et al., 1986; Dewey et al., 1989). Pop nets are set and retrieved by two individuals and are easily dissembled for easy transport.

4.7.2 Pop nets (Figure 13) are rectangular devices, constructed of lightly tarred 6.4 mm mesh netting. They are 1.8 m wide x 3.1 m long x 1.8 m high when released and enclose an area of 6.5 m^2. The top of the net is attached to a rectangular polyvinylchloride frame filled with foam. The top of the frame should be painted black to reduce the effect of color on fish avoidance or attraction. They are designed to be set from the surface and released with a mechanical device.

4.7.3 The pop net used in nonvegetated areas can simply be a rectangular holding net with its top attached to the buoyant frame and its bottom panel attached to a frame, 19 mm diameter galvanized pipe. After the pop net is tripped, the net and attached frames are picked up and carried to shore as a unit.

4.7.4 The enclosed bottom design pop net cannot be used in vegetated areas. A pop net used in vegetated areas is constructed with an open-bottom. Its bottom is split down the center and attached only along the two long sides of the holding net. The bottom frame is still present but used only to hold the buoyant top frame in position during the setting process and is not attached

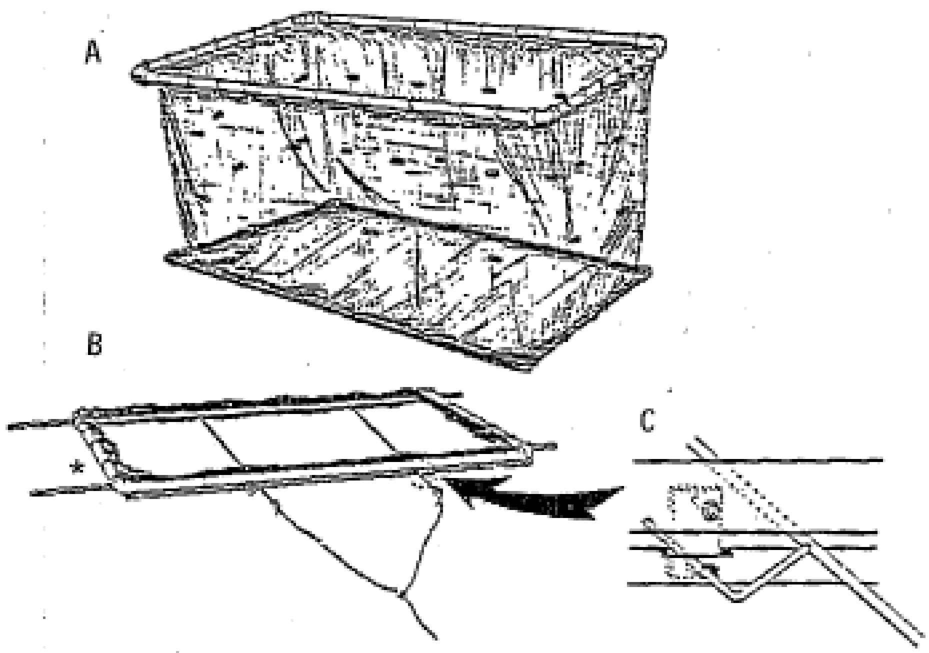

Figure 13. Pop net. A. model for nonvegetative site after release. B. Pop net set for release in vegetated site, show pipes used for bottom closure (*) and position of release mechanism (arrow). C. Release mechanism. From Dewey et al. (1989).

at all to the holding net. Galvanized pipes 3.7 m long, are attached to each of the two split sections and are used to hold the bottom sections to the sides as the pop net is placed over vegetation (Figure 13,B). After the pop net is released, these pipes are used to purse the bottom sections together and thus enclose the catch. The sample is retrieved by carrying the top frame, attached net, and pursing pipes to shore as a unit. The bottom frame is retrieved separately.

4.7.5 Pop nets have two release mechanisms (Figure 13,B and C), each consisting of two devices at opposite sides of the net. At each position, a piece of aluminum flat bar, attached to the top frame, fits into a slot in the bottom frame. An L-shaped extension attached to the trip rod fits through matching holes in the flat bar and in the bottom frame to hold the top and bottom frames together. The trip rods for both mechanisms are joined by a lead core line, to which is tied a 5 cm trip cord. When the trip cord is pulled, both trip rods release simultaneously, allowing the buoyant top frame to rise. In the set position, these release mechanisms hold the upper and lower frames together in a low profile (9.5 cm high), which increases stability in currents.

4.8 Miscellaneous Fish Methods

4.8.1 Underwater Methods

4.8.1.1 Direct observation techniques can be used to study the structure of fish assemblages, spawning, feeding, and movement, etc. For techniques on direct underwater observation which involve the use of divers (snorkeling and scuba) to study fish populations, see Helfman (1983) and Pearsons et al. (1992).

4.8.2 Hydroacoustic Techniques

4.8.2.1 Hydroacoustic assessment techniques are generally applied to methods which use equipment such as sonars or depthsounders. The hydroacoustic techniques use sound from these devices that are actively transmitted and information extracted from the returning echoes to detect fish and make qualitative and quantitative estimates of biomass. For a review, discussion, and guidelines of fishery hydroacoustics, see Thorne (1983).

4.8.2.2 Information on hydroacoustic equipment for fisheries evaluations can be obtained from the following company:

Hydroacoustic Technology, Inc.
715 NE Northlake Way
Seattle, WA 98105, Telephone (206) 633-3383.

4.8.3 Underwater Biotelemetry

4.8.3.1 These techniques are often used to monitor the locations, behavior, and physiology of free-ranging fish, and involves attaching a device that relays biological information. For a review and discussion of telemetry methods, see Winter (1983).

4.8.3.2 Information on a field proven digitally encoded radio telemetry system for fisheries evaluations can be obtained from the following company:

Lotek Engineering, Inc.
115 Pony Drive
Newmarket, Ontario, Canada L3Y 7B5
Telephone (416) 836-6680

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